Controlling effects of forest belts on non-point source pollution of agricultural lands in Taihu Lake area, China

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Abstract: Taihu Lake area is one of the most developed areas in agricultural production. Application of fertilizers and pesticides in large quantities greatly aggravate environmental pollution of this area, and water pollution has worsened to an unbearable condition. Two sampling farms (respectively 1 hm^2) under rape-rice rotation and wheat-rice rotation were selected as studied ecosystem and a 5-yr-old Poplar forest and 8-yr-old Metasequoia forest were chosen in the selected areas. By collecting samples of Nitrogen, Phosphorus in water, crops and underground of forest, the transfer and loss of N and P (main water pollutants) in faming ecosystem were studied, and the effects of forest belts on non-point source pollution of agricultural lands was analyzed. The results indicated that the transfer and loss of N and P vary with means of rotation, types of crops and the amount of fertilizer application. Buffering forest belts betweens farmlands and ditches can effectively stop and purify such elements as N and P in soil runoffs, thus controlling non-point source pollution of agricultural lands. When the width ratio of farmland to forest belt is 100 to 40, 50.05% losing N, 29.37% losing P can be absorbed by forest under rape-rice rotation and 30.98% N, 86.73% P can be absorbed by forest under wheat-rice rotation. When the width ratio of farmland to forest belt is 150 to 40, 33.37% losing N, 19.58% losing P can be absorbed by the forest under rape-rice rotation, and under wheat-rice rotation 20.65% lost N and 57.82% lost P can be absorbed. There is only some purification effect when the width ration of farmland to forest belt is 200 to 40. Based on model of buffering forest belts, the width ratio of farmland to forest is determined between 100 to 40 and 150 to 40, because it not only can purify water, but also occupy less farmland. It is suggested that Poplars, with the characteristics of fast-growing and high value, are suitable to be planted as shelter-forest in Taihu Lake Watershed.

Key words: Agriculture; Non-point source pollution, Ultrophication, Nitrogen, Phosphorus, Forest belt, Sustainable development
CLC number: S727.28; S727.24 **Document code:** A **Article ID:** 1007-662X(2002)03-0213-04

Introduction

China ranks as the largest fertilizer-consuming country in the world. Its annual consuming amount of fertilizer reaches 3.6×10^{10}kg. Although fertilizer can promote the food production to a certain degree, the irrational use of it has caused pollution of water bodies. Of the total 130 large-scale lakes in China, more than 60 lakes have already been seriously polluted including water source ultrophication. Taihu Lake area is one of the most developed areas in agricultural production. In this area fertilizers and pesticides consumed for agricultural purpose are 3.0×10^9 kg and 1.0×10^8 kg, respectively, per year, and a certain amount of which flows into rivers and lakes with soil runoffs. Application of fertilizers and pesticides in large quantities greatly aggravate environmental pollution of this area, and water pollution has worsened to an unbearable condition, greatly affecting social and economic development. Many studies were carried out on non-point source pollution (Ma 1987; Zhang 1993; Ma 1992), control (He 1998; Chen 2000; Liu1997) and prevention (Jin, 1999, 1998), but the control effects of forest belts on non-point source pollution of agriculture were less reported in China. In this paper, the control effects of forest belt on non-point source pollution of agricultural land was studied in Taihu Lake area

Study site

The experiment plot is located in Kunshan city, a typical city in Taihu Lake Watershed (30°5'~32°8' N, 119°8'~121°55' E). This area belongs to monsoon climate area between southern part of North sub-tropic and northern part of Middle sub-tropic, with clear seasons, long frost-free period, rich heat and precipitation (1073 mm annually). Soil is intensively utilized by farming, forestry, animal husbandry, and sideline production, and fishery development is at high levels. Along with development of farming-forestry-animal husbandry as well as farming-sideline production-fishery, a serials of soil utilizing methods has been formed. In this well-known land of fish and rice, wheat (rape)-rice-rice cropping system were popular in 1970s, and at present, wheat (rape)-rice system is predominant.

Foundation item: This paper was supported by the Environmental Protection Foundation of Jiangsu Province (2000(_)0009), National Natural Science Foundation of China (NSFC39970605)
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Received date: 2002-6-14
Responsible editor: Chai Ruihai

Testing methods

Two ecosystems composed of rape-rice and wheat-rice, as two different rotating methods, were selected The application amount of fertilizer for rape is: compound fertilizer ($N\text{-}P_2O_5\text{-}K_2O$=15-15-15) 600 kg/hm^2 and urea (N≥44%) 225 kg/hm^2; for wheat: compound fertilizer 600 kg/hm^2 and urea 300 kg/hm^2; and for rice is: compound fertilizer 300 kg/hm^2, urea 450 kg/hm^2 and NH_4HCO_3 450 kg/hm^2 (N≥ 17.1%).

A measuring tool for rainfall was set up in the selected typical areas for regular collection of water samples. Another container with plastic net above to avoid insects' falling was set up to collect dust particle. The collected particles were washed by distilled water, after then they were dried, weighed, and analyzed. When wheat, rape and rice were harvested, crop samples were collected in the typical areas, and seeds and straw were taken separately. After being weighed and dried, the collected samples were smashed, then filtered through a 2-mm boult and preserved in plastic sacks for further measurement. A 5-yr-old Poplar forest (13.5 m in height, 16.7 cm in diameter, and) and a 8-yr-old Metasequoia forest (7.4 m in height, 9.10 cm in diameter, and) in the selected areas were chosen in March 2001. The forest samples at surface and underground samples were collected separately, and the samples were put into plastic sacks for preservation after being dried, smashed, filtered. The analysis of plant and water samples was based on relevant criteria.

Results and analysis

The losing nutrients of agricultural non-point sources under various rotation systems

Farmland plays a key role in nutrient cycle in farm ecosystem. The balance of nutrients in farmland decides the productivity and durability of the ecosystem, the efficiency of nutrient input and environmental consequence. As a result, the study of nutrient balance condition in farm ecosystem and the analysis of soil nutrient output and input in various land utilization ways are of great significance to the prevention of leaking of nutrients in farm ecosystem. The nutrient balance in farmland ecosystem is determined by the input and output along the ecosystem border. Ecosystem balance method was introduced in this study. The lost amount of N and P can be calculated according to annual N, P input and output in the selected area, and finally the influential appraisal on effects on the lakes ultrophication caused by farming operation could be made. The input and output factors of the ecosystem were shown as Fig 1 .

Two sampling farms (respectively 1 hm^2) under rape-rice rotation and wheat-rice rotation were selected as studied ecosystem. The input and output nutrients of the ecosystem was studied in detail. According to the amount of fertilizer, nitrogen fixation, rainfall, dust particle, irrigation, crop harvest, and gaseous loss, the balance condition of N, P in two selected farm ecosystems can be figured out. Details were shown in Table 1.

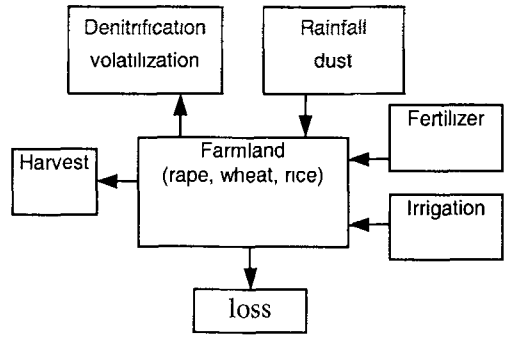

Fig. 1 The input and output factors of farm ecosystem

Table 1. The balance condition of nutrients in two farm ecosystem s (kg hm^{-2}a^{-1})

Contents	Wheat-rice		Rape-rice	
	N	P	N	P
Compound fertilizer	135.00	58.92	135.00	58.92
Nitrogenous Fertilizer	406.50	-	373.50	-
Nitrogen fixation	48.00	-	48.0	-
Rainfall	10.13	0.22	10.13	0.22
Dust particle	0.16	0.03	0.16	0.03
Irrigation	3.90	0.54	3.90	0.54
Total input(1)	603.69	59.71	570.69	59.71
Crop harvest	288.09	57.17	285.35	52.21
Gaseous loss	236.20	-	236.20	-
Total part output(2)	524.29	57.17	521.55	52.21
Losing =(1) - (2)	79.40	2.54	49.14	7.50

Table 1 shows that there exists a difference in the amount of nutrient input and output under various rotation ways. Under rape-rice rotation, the annual amount of N and P lost in harvest is 285.35 kg and 52.21 kg respectively, among which the rice occupies a bigger share, while under wheat-rice rotation, the amount of losing N and P in a year is 288.09 kg and 57.17 kg respectively, among which rice occupies a bigger share because rice output is higher than wheat and rape output. The study results suggest that the amount of losing N and P by harvest under different rotation way is different. It provides relevant reference for the control of crop fertilizer in different rotating methods. Table 1 also shows that the amount of losing gaseous N is high in both N input in two crop-rotation ways. Therefore, special attention should be paid to the amount of input and way of using the chemical N fertilizer, enhancing its effectiveness and avoiding the volatilization which may pollute the air and the loss caused by rainfall which may pollute the water.

According to the analysis of the nutrient balance condition in farm ecosystem in typical areas, properly input nutrients not only can keep and enhance soil fertility, but can help to

maintain soil productivity and stability of farm ecosystem. If nutrients input goes far above the level of economically input amount, fertilizer marginal effect drop drastically and the losing nutrients to outside ecosystem increase. Not only will this cause great waste of resources, but will have side effects on the environment.

The species of the tree for forest belts

From above results, a lot of nutrients in farmland go with water, which flow mainly into the rivers nearby and cause pollution. Because forest has powerful absorption capability, shelter-forest between farmland and water body can be planted to absorb nutrients that go with water. Studies show that the forest belts between farmland and water body not only help purify water, but also improve regional farming climate and offer a better view of the landscape.

If forest belts are to be set up between farmland and water body, both the preventive effect of the forest belts and biological characteristics and economic value of the selected forest species should be taken into account. In addition, tree species should be selected, which is tall, durable resistant to the wind, adaptable to the climate and soil condition, and highly valuable. According to the conditions of the selected area, two popular tree species, poplar and Metasequoia, are selected as study subjects. Growth characteristics and nutrient-absorption characteristics are studied elaborately. According to Table 2, poplar is selected because it is of pleasant appearance and wide use, easy to reproduce and adapt to the environment.

Table 2. The amount of N, P absorbed by each poplar and Metasequoia (g)

Metasequoia (eight-years old)		poplar (five-years old)	
N	P	N	P
564.67	30.55	585.67	52.47

The model of forest belts

Farmland is decreasing annually in Taihu Lake area with relatively developed economy, a large population and comparatively small areas of land. If forest belts are to be set up as the model of Fig. 2, the width ratio of forest belts to farmland should be studied with great efforts. The purification effect and land-use capability are closely related to the rational ratio of forest belts to farmland. Three different farmlands are selected as study subjects, whose length is 100 m, and width is 100 m, 150 m and 200 m respectively. Generally speaking, after selective felling, the distance between two lines of poplar is 5m×5m, the width of the forest belts is 20 m. Based on the regularity of forest planting and available data, about 210 poplars are needed in all according to the model of Fig 2. These poplars, in theory, can absorb 122 976 g N and 11 014.5 g P within five years. The purification effect of forest belts on the nutrients losing from farm ecosystem can be obtained on the basis of Table 3. The detailed results were shown in Table 4.

When the width ratio of farmland to forest belt is 100 to 40, according to Table 4, the purification effect on the losing nutrients is the best and 50.05% losing N, 29.37% losing P can be absorbed by forest under rape-rice rotation and 30.98% N, 86.73% P can be absorbed by forest under wheat-rice rotation. Under this circumstance the purifying ability of water is very satisfactory. When the width ratio of farmland to forest belt is 150 to 40, 33.37% lost N, 19.58% lost P can be absorbed by the forest under rape-rice rotation, while under wheat-rice rotation 20.65% lost N and 57.82% lost P can be absorbed. There is only some purification effect when the width ratio of farmland to forest belt is 200 to 40. According to the previous analysis, it is suitable when the width ratio of farmland to forest between 100 to 40 and 150 to 40, because it not only can purify water, but also occupy less farmland.

Fig. 2 farm and forest belts model

Table 3. Amount of the nutrients losing from farm ecosystem in deferent ways of crop rotation (kg)

Farmland width	Rape-rice		Wheat-rice	
	N	P	N	P
100m	245.70	37.50	397.00	12.70
150m	368.55	56.25	595.50	19.05
200m	491.40	75.00	794.00	25.40

Table 4. Forest belts purification effect on the nutrients losing from farm ecosystem(%)

Farmland width	Rape-rice		Wheat-rice	
	N	P	N	P
100m	50.05	29.37	30.98	86.73
150m	33.37	19.58	20.65	57.82
200m	25.03	14.69	15.49	43.36

Other crops can be cultivated in the forest belt between farmland and ditch. They can help enhance soil utilization ratio, increase economic income, offset the decreasing income caused by planting, absorb the losing nutrients from the farmland and purify water body.

Conclusions and suggestion

Nutrients-balance effect in the farm ecosystem under two different crop rotations is different in the study area. The amount of losing N in wheat-rice rotation is higher than that

in rape-rice rotation, while the losing of P in wheat-rice rotation is less than that in rape-rice rotation. The amount of losing gaseous N in two crop rotations is high. The way of fertilization should be heeded and the amount of fertilization should be controlled. The balance of nutrients in the farm ecosystem should also be heeded. When nutrients are deficient or surplus, the equilibrium of nutrients in the farm ecosystem will be disturbed and the whole ecosystem environment will be endangered.

Appropriate forest belts between farmland and water body can prevent the water pollution caused by the losing nutrients from the farmland, and improve the climate and enhance the landscape as well. Poplar with the characteristics of quick-growing and high value is more suitable than Metasequoia to be planted as shelter-forest in Taihu Lake Watershed. Studies show that the width ratio of farmland to forest belt in Taihu Lake area is suitable between 100 to 40 and 150 to 40. Such forest belt between the farm and water body can not only purify water quality, but also occupy less cropland.

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